Risk Perception, Assessment, and Management

Risk perception, assessment & manag.

- Hazard, exposure, and risk
- Thinking about risk
- Risk assessment processes
- Risk management

Hazard, exposure, and risk

- **Hazard**: the inherent properties of a substance, object, or activity with a potential for adverse or harmful effects to occur

- **Exposure**: a quantitative measurement to the extent to which a given hazard is present

- **Risk**: the probability that an adverse effect will occur to someone

Hazard, exposure, and risk - example

- Hazard: arsenic (As) is a human carcinogen
- Exposure: a 60-kg person in Bangladesh drinks 2 L water containing 90 µg/L As everyday
- Risk: using the carcinogenicity data for As and the given exposure, the person has 0.2% possibility of cancer development caused by As ingestion in his entire life

P&G, 2012

Thoughts about risk: public risk perception

Orders of perceived risk for 30 activities or technologies

Activity or technology	College students	Experts	Activity or technology	College students	Experts
Nuclear power	1	**20**	Contraceptives	9	**11**
Handguns	2	**4**	Fire fighting	10	**18**
Smoking	3	**2**	Surgery	11	**5**
Pesticides	4	**8**	Food preservatives	12	**14**
Motor vehicles	5	**1**	Spray cans	13	**26**
Motorcycles	6	**6**	Large construction	14	**13**
Alcoholic beverages	7	**3**	Private aviation	15	**12**
Police work	8	**17**	Commercial aviation	16	**16**

Slovic (1987), Science

Thoughts about risk: public risk perception

TABLE 4.5 Some characteristics that elevate the perception of risk.

Attributes that elevate the perception of risk	Attributes that lower perception
Involuntary	Voluntary
Exotic	Familiar
Uncontrollable	Controllable
Controlled by others	Controlled by self
Dread	Accept
Catastrophic	Chronic
Caused by humans	Natural
Inequitable	Equitable
Permanent effect	Temporary effect
No apparent benefits	Visible benefits
Unknown	Known
Uncertainty	Certainty
Untrusted source	Trusted source

Masters (1998) Introduction in Environmental Engineering and Science, 2nd ed.

Thoughts about risk: cost-effectiveness

Life-saving interventions and their cost-effectiveness

Interventions	$/life-year saved*
Chlorination of drinking water	$3,100
Radon remediation in homes with levels ≥ 21.6 pCi/L	$6,100
Radon remediation in homes with levels ≥ 8.11 pCi/L	$35,000
Radon remediation in homes with levels ≥ 4 pCi/L	$140,000
Mandatory seat belt use law	$69
Improve educational curriculum for beginning drivers	$84,000

*in 1993 dollars

Tengs et al. (1995), Society for Risk Analysis

Thoughts about risk: “How clean is clean?”

You applied a soil remediation technology to reduce Cu concentration in a contaminated soil down to 200 mg/kg. This is still above the regulation level of 150 mg/kg. You searched nearby areas which are not contaminated and found that the background Cu concentration is 30-250 mg/kg.

Is the soil clean?

You tested with the soil to find that there’s no possibility for Cu to be released out from the soil.

Now, is the soil clean?

How clean is clean???

Thoughts about risk: implications

Environmental problems need to be managed based on ***risk*** that is properly estimated in order to protect the human health in an efficient and cost-effective manner, and to persuade the general public

- (Quantitative) risk assessment: quantification of a risk at a certain situation
- Risk management: the use of the results of a risk assessment to make policy decisions

US EPA's risk assessment process

For human risk assessment:

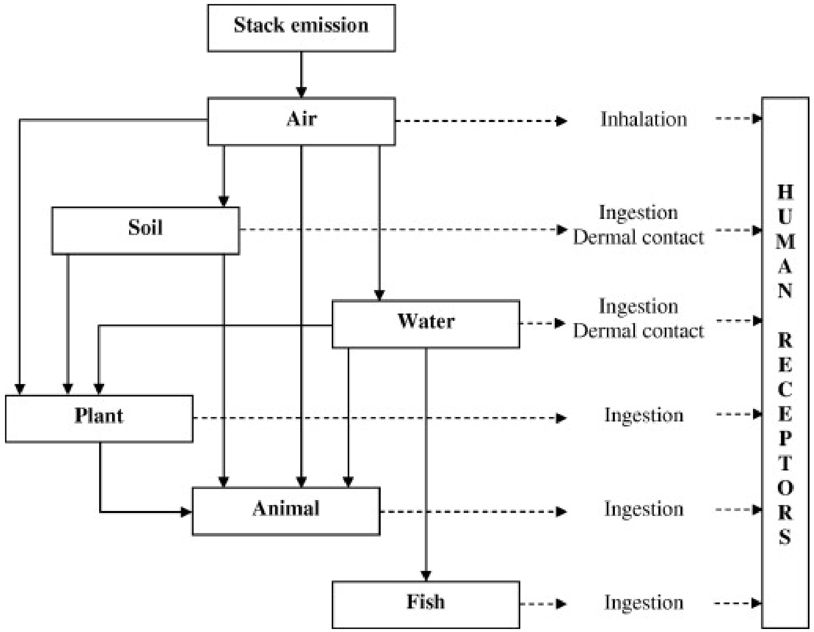
- Data collection and evaluation
- Toxicity assessment
- Exposure assessment
- Risk characterization

* Risk assessment is considered to be *site-specific*: the whole steps of a risk assessment is conducted for every contaminated site

Data collection and evaluation

- Collecting background information of a site
  - Possible contaminants
  - Concentrations of the contaminants in key sources and media (air, soil, water, …), characteristics of sources, and information related to the chemical's release potential
  - Characteristics of the environmental setting that could affect the fate, transport, and persistence of the contaminants

- Form a "conceptual site model": initially identify potential exposure pathways and exposure points important for assessing risk



Example conceptual site model

Toxicity assessment

- Determining the relationship between the exposure to a contaminant and the increased likelihood of the occurrence or severity of adverse effects

1. Hazard identification

   determines whether exposure to a contaminant causes increased adverse effects

2. Dose-response evaluation

   describes how the adverse effects are related to the dose provided to humans

Toxicity assessment

2. Dose-response evaluation (continued)

– dose: the mass of chemical received by an exposed individual (mg contaminant / kg body mass)

– response: can be any adverse effects such as reduced body weight, reduced fertility, tumor formation, and death

http://www.dailymail.co.uk

"The dose makes the poison"

- All chemicals can be toxic if too much is eaten, drunk, or absorbed

Q: All chemical can be non-toxic if very little is eaten, drunk, or absorbed?

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Strange but True: Drinking Too Much Water Can Kill

In a hydration-obsessed culture, people can and do drink themselves to death.

Jun 21, 2007 | By Coco Ballantyne

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Liquid H_2O is the sine qua non of life. Making up about 66 percent of the human body, water runs through the blood, inhabits the cells, and lurks in the spaces between. At every moment water escapes the body through sweat, urination, defecation or exhaled breath, among other routes. Replacing these lost stores is essential but rehydration can be overdone. There is such a thing as a fatal water overdose.

Earlier this year, a 28-year-old California woman died after competing in a radio station's on-air water-drinking contest. After downing some six liters of water in three hours in the "Hold Your Wee for a Wii" (Nintendo game console) contest, Jennifer Strange vomited, went home with a splitting headache, and died from so-called water intoxication.

Toxicity assessment: terminologies

- **Acute toxicity**: an adverse effect that has a rapid onset, short course, and pronounced symptoms

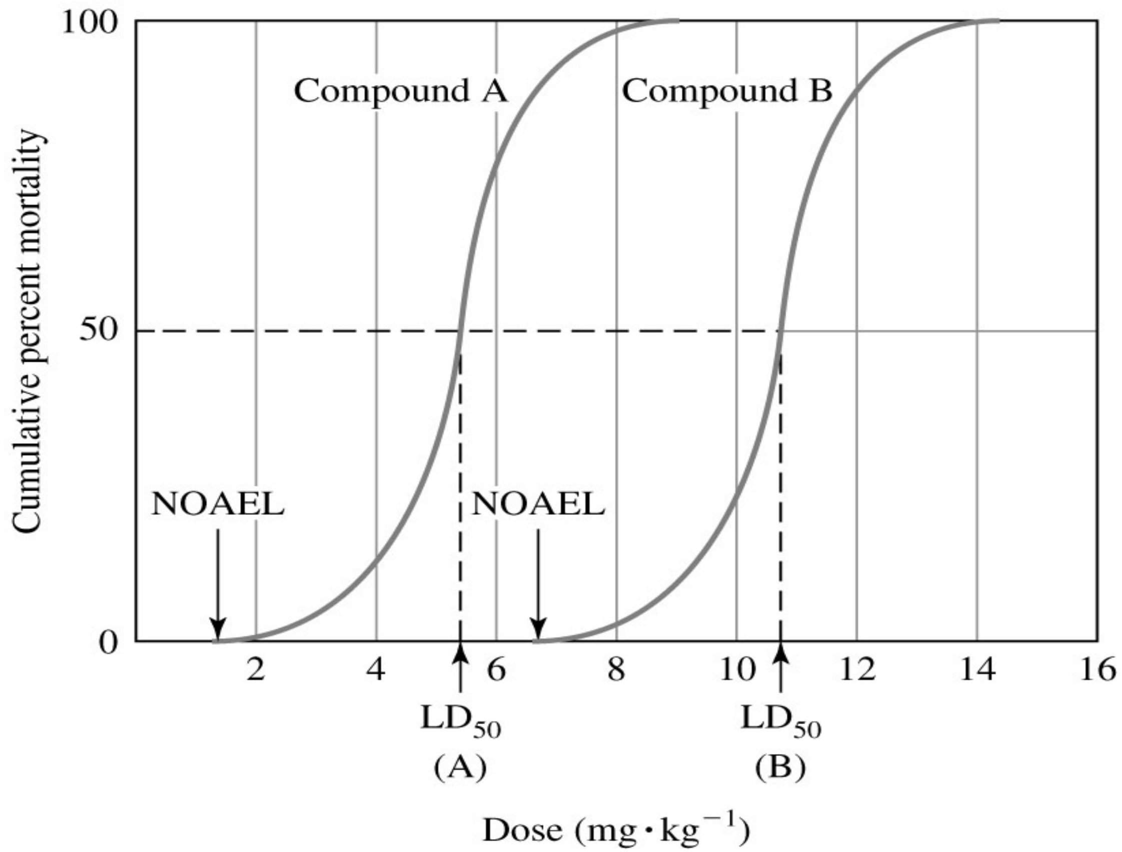
- **Chronic toxicity**: an adverse effect that frequently takes a long time to run its course and initial onset of symptoms may go undetected (ex: carcinogenesis)

- **Carcinogenesis**: creation of cancer (transformation of normal cells into cancer cells)

- **Carcinogen**: a cancer-producing substance

Toxicity assessment

- Dose-response curve



NOAEL:

No **O**bserved **A**dverse **E**ffect **L**evel

LD50:

Lethal **D**ose for **50**% of the population

Toxicity assessment

- Non-carcinogenic vs. carcinogenic risk
  - Non-carcinogenic risk: It is believed that there is a safe dose (*NOAEL* exists), i.e., the body can repair itself. From the *NOAEL* of a dose-response relationship, reference dose (*RfD*) is estimated:

$$RfD = NOAEL/10^{x},$$

(1≤x≤3; safety factors for animal/human differences & variation within humans)

  - Carcinogenic risk: Assume no safe dose (no *NOAEL*). At low doses, the slope of the dose-response curve is represented by a ***slope factor*** (SF).

Exposure assessment

- Estimate the magnitude of exposure to chemicals of potential concern
- The exposure concentrations are predicted, then the <u>pathway-specific intakes</u> are calculated as:

$$CDI = C\left[\frac{CR \times EFD}{BW}\right] \times \frac{1}{AT}$$

* This is a simplified & generalized version; you may find more complicated forms in textbooks

CDI = chronic daily intake (mg/kg body weight/day)
C = chemical concentration (ex: mg/L water);
CR = contact rate (ex: L/day)
EFD = exposure frequency and duration (= EF x ED)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)

Exposure assessment

Q: Estimate the lifetime average chronic daily intake of benzene from exposure to a city water supply that contains a benzene concentration of 0.005 mg/L. Assume the exposed individual is an adult male who drinks 2 L of water every day for 63 years and ingestion of benzene in drinking water is the only exposure pathway. The averaging time (AT) is 75 years (=27375 days).

Risk characterization

- For **carcinogenic risk** (risk below 0.01),

  Risk = (intake)(slope factor)

  For multiple substances and multiple pathways,

  $$\text{Total exposure risk} = \sum \text{Risk}_{ij}$$

  i = compounds; *j* = pathways

  * Goal: ensure risk < 10^{-4} to 10^{-6}

Risk characterization

- For non-carcinogenic risk,

  calculate Hazard Index (HI):

  HI = (intake)/(*RfD*)

  For multiple substances and multiple pathways,

  $HI_T = \sum HI_{ij}$ i = compounds; j = pathways

  * Goal: ensure $HI_T < 1$

Risk characterization

Q: Using the previous example, estimate the carcinogenic risk by ingestion of benzene in drinking water.

(benzene slope factor for oral ingestion = 0.015 kg·day/mg)

Risk management

- Based on the risk assessment result, action is taken/not taken to reduce the existing risk to an acceptable level

- Strategies to reduce risk
  - Lower the concentration

    apply engineering techniques to reduce concentrations in the environmental media (can be the source or significant exposure route)

  - Engineering control for the exposure

    ex) solidification of contaminated soil; blocking surface runoff release from the site

  - Institutional control for the exposure

    ex) restrict public access to a contaminated site

Reading assignment

- Textbook Ch6 p. 234-249

Exposure assessment

Slide#19 solution)

$$CDI = C\left[\frac{CR \times EFD}{BW}\right] \times \frac{1}{AT}$$

C = benzene conc. = 0.005 mg/L

CR = contact rate = 2 L/day

EFD = exposure frequency and duration = EF x ED

= (365 days/year) x (63 years) = 22995 days

BW = body weight = 70 kg

AT = averaging time = 75 years = 27375 days

$$CDI = 0.005\ mg/L \times \frac{2\ L/day \times 22995\ days}{70\ kg} \times \frac{1}{27375\ days} = \mathbf{1.2 \times 10^{4}\ mg/kg - day}$$

Risk characterization

Slide#22 solution)

$CDI = 1.2 \times 10^{4}\ mg/kg - day$

Carcinogenic risk = (CDI) x (slope factor)

= (1.2 x 10^{-4} mg/kg-day) x (0.015 kg-day/mg)

= ***1.8 x 10^{-6}***

→ *The man has a 1.8/1,000,000 chance of developing cancer because of benzene ingestion by drinking water.*